TABLE

Impact of the process flow rate on the reactor performance with 0.015" deep features at 700 C and 25 atm for methane reforming

20% activity		Methane conversion	E_factor
	Baseline	19.8%	
	0.015: SF	27.3%	37.5%
20% more	Baseline	17.2%	
flow	0.015: SF	24.2%	40.3%
20% less	Baseline	23.3%	
flow	0.015: SF	31.1%	33.4%

At the 20% of baseline activity level for the SMR reaction rate, the methane conversions for all the cases considered are far away from the equlibrium value at 700 C (~44%). As shown in the Table, the deepest features were found to give the highest enhancement. A further increase in enhancement was surprisingly seen when the flowrate was increased over the baseline flowrate. The enhancement was less as the flowrate decreased. For the latter case, the lower velocity from the lower flowrate decreased the flow rotation for this fixed geometry and thus slightly reduced the enhancement factor. As the flowrate increases so does the overall velocity and thus the imparted transverse and perpendicular velocity created by the surface features. As the kinetics are slower than the baseline case, the effect of surface features becomes more important—in part becuase the baseline kinetics for this study were very fast.

[0212] The higher flowrate also corresponds to a higher Reynolds number. As the Reynolds number is increased the molecules spend a larger fraction of time within the active surface features and as such they have more time at or near the catalyst for the reaction to occur.

TABLE

Impact of the channel gap size on the reactor performance (gap size: 0.04"), 700 C., 25 atm, SMR reaction, 0.01" deep surface features

20% activity		conversion	E_factor
Base flow	Baseline	7.6%	
rate	0.010: SF	10.1%	31.9%
50% more	Baseline	5.4%	
flow	0.010: SF	7.2%	34.8%
50% less	Baseline	13.6%	
flow	0.010: SF	17.2%	25.9%

For the cases shown in this table, a much larger gap was modeled. A much larger gap was used and as expected a larger enhancement factor was seen. The comparable case for the 20% baseline activity and base flowrate for 0.01" deep surface features was an enhancement factor of 26.6% for a 0.0125" gap versus 31.9% for the 0.04" gap. The trend with a higher enhancement factor for a higher flow case is also seen for the large gap case.

Example

Heat Transfer Enhancement Using Surface Features

[0213] Surface features induce rotating or helical flow-paths which improve the heat transfer from the wall to the bulk of the fluid or vice versa. The improvement in heat transfer introduced by surface features was estimated using computational fluid dynamics. The tool used was Fluent V 6.1.22.

[0214] The CFD models were built for two micro-channels differing in the smallest dimension. One channel had a gap of 0.0125" while the other had a gap of 0.040". For each gap size, two models were built: 1) without surface features and 2) with surface features to estimate the heat transfer enhancement respectively.

[0215] The CFD models were built using Gambit V2.2.30. The details of the channel dimensions and surface features are shown in FIG. **1-3**. The main channel dimension is 4.06 mm wide, 1.02 mm gap and 36.83 mm long. The length of the main channel between initial 3.81 mm and final 5.08 mm of the main channel length had surface features as shown in FIG. **6**. The surface feature pattern is similar to the one proposed in the SHM but not in the dimensions or number of microchannel walls containing features nor the use of fill features as used in this example. The surface features are 0.38 mm open separated by 0.38 mm wall and are 0.25 mm deep and used on both sides of the microchannel.

[0216] The mesh for the computational fluid analysis was developed in Gambit. The total number of cells was 131106, total number of faces was 542409 and total number of nodes was 177006. The mesh was generated to keep it a regular mesh as much as possible.

[0217] Two fluids were considered for determining mixing efficiency of the surface features. The properties and operating conditions of the fluids is given below:

[0218] 1) Gas

[0219] a. Outlet pressure=345 psi

[0220] b. Inlet temperature=300 K

[0221] c. Viscosity=1.28×10^{-5} kg/m/s

[0222] d. Thermal conductivity=0.087 W/m/K

[0223] e. Specific heat=2768.03 J/kg/K

[0224] f. Density=Using ideal gas law

[0225] g. Molecular weight=17.49 g/mol

[0226] h. Molecular diffusivity=1×10^{-5} m^2/s

[0227] 2) Liquid Water

[0228] a. Outlet pressure=14.7 psi

[0229] b. Operating temperature=300 K

[0230] c. Viscosity=1.0×10^{-3} kg/m/s

[0231] d. Thermal conductivity=0.6 W/m/K

[0232] e. Specific heat=4182 J/kg/K

[0233] f. Density=998.2 kg/m^3

[0234] g. Molecular weight=18.01 g/mol

[0235] h. Molecular diffusivity=1×10^{-9} m^2/s

Case 1: 0.0125 Inch Channel Gap

Using liquid water as the fluid:

Boundary Conditions

[0236] Operating pressure=14.7 psi

[0237] Outlet pressure=0 psig